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Comparison of Retaining Replacement Heifers in a Straight-bred Angus System Versus Purchasing Crossbred Replacement Heifers to Be Bred to a Terminal Sire

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COMPARISON OF RETAINING REPLACEMENT HEIFERS IN A STRAIGHT-BRED ANGUS SYSTEM VERSUS PURCHASING CROSSBRED REPLACEMENT HEIFERS TO BE BRED TO A TERMINAL SIRE

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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-GDR

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ABBREVIATIONS

ADF	acid detergent fiber
ADG	average daily gain
ADL	acid detergent lignin
AI	artificial insemination
BW	body weight
C	Celsius
CAB	certified angus beef
CCERF	Cow-Calf Education and Research Facility
CO	Colorado
CP	crude protein
d	day
DE	digestible energy
DM	dry matter
DMI	dry matter intake
EBG	empty body gain
EBW	empty body weight
EPDs	expected progeny differences

EQEBW	equivalent empty body weight
EQSBW	equivalent shrunk body weight
FA	fat
F:G	feed : gain
FI	feed intake
FFG	feed for gain
FFM	feed for maintenance
FSBW	final shrunk body weight
F_1	first generation cross-bred
G:F	gain : feed
h	hours
hd	head
HR	home-raised
kg	kilogram
LEA	Livestock Enterprise Analysis
LMIC	Livestock Marketing Information Center
Mcal	megacalories
ME	metabolizable energy

MT	Montana
N	nitrogen
NDF	neutral detergent fiber
NDF_N	nitrogen free neutral detergent fiber
NAAB	National Association of Animal Breeders
NE	net energy
NE_m	net energy for maintenance
NE_g	net energy for gain
NRC	Nutrient Requirements of Cattle
PR	purchased replacement
RE	retained energy
RFI	residual feed intake
SBW	shrunk body weight
SDSU	South Dakota State University
SRW	shrunk reference weight
SWG	shrunk weight gain
TDN	total digestible nutrients
WW	weaning weight

WY	Wyoming
yr	year

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ABSTRACT

COMPARISON OF RETAINING REPLACEMENT HEIFERS IN A STRAIGHT-BRED ANGUS SYSTEM VERSUS PURCHASING CROSSBRED REPLACEMENT HEIFERS TO BE BRED TO A TERMINAL SIRE

GRADY DOUGLAS RUBLE

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Two evaluations were conducted to evaluate the biological and economic production efficiency of retaining replacement females in a straight-bred Angus herd (HR) as opposed to purchasing crossbred replacements for a terminal sire production system (PR) where maximum maternal and individual heterosis is achieved. The first study was a comparison of the HR system versus PR system. It was modeled after a 100 hd, straight-bred Angus cowherd that raises their own replacement females. The (NASEM, 2016) model was used to determine the required metabolizable energy (ME)/animal for each stage of production. Stages were broken into segments including weaning – d 28, d 29 – breeding, breeding – mid-gestation. It was determined, that on the same ME resources, an operator can run 117 cows and produce 7,833 more kilograms in the PR system compared to the 100 cows in the HR system. Economically, the PR system produced $10,949 more dollars of net income than the HR system. In the second study, 25 Angus and 29 SimAngus heifers were placed in the South Dakota State University Cow Calf Education and Research Facility Insentec feeding system, where they were evaluated for dry matter intake, average daily gain, gain:feed, metabolizable energy intake, predicted dry matter intake, and residual feed intake based on NRC prediction equations. At the

start of the trial there was no difference in initial BW. The first period (d 1 - 98) featured no difference in BW, DMI, G:F, ME intake, predicted DMI or RFI_{NRC}. However, Angus heifers exhibited a greater ADG ($P \leq 0.02$) than SimAngus heifers. During period 2 (d 99 - 167), heifer BW, G:F, and RFI_{NRC} were not different between breeds; however, Angus heifers had a greater ADG ($P \leq 0.02$), DMI ($P < 0.01$), ME intake ($P < 0.01$) and predicted DMI ($P \leq 0.04$). Cumulatively (d 1 - 167) Angus heifers had greater ADG ($P < 0.01$), DMI ($P \leq 0.03$), G:F ($P \leq 0.05$), ME intake ($P \leq 0.03$), and tended to have greater predicted DMI ($P \leq 0.06$) than SimAngus heifers, but no difference was observed in RFI_{NRC}. Contrary to our initial assumptions, these results show that in this herd, Angus heifers have the advantage in performance, feed intake and efficiency over SimAngus heifers. These results warrant further research with a larger sample size and greater genetic diversity, in order to draw compelling conclusions that explain these biological differences.

CHAPTER ONE

INTRODUCTION AND REVIEW OF LITERATURE

Objective

To analyze the impact of raising straight-bred replacement heifers versus purchasing crossbred replacement heifers on energy intake, total cow carrying capacity and total kilograms of production.

Hypothesis

Purchasing crossbred replacement females is a more efficient way to capitalize on the advantages of crossbreeding and will increase cow carrying capacity and total kilograms of production relative to raising straight-bred replacement females.

Introduction

The U.S. has a total of 30.2 million beef cows and 6.34 million replacement heifers. South Dakota, alone, is home to 1.67 million of those beef cows and 375,000 replacement heifers (USDA, 2017).

A major decision producers face is how to utilize their resources relative to mature cows and replacements. The options being raising replacement females or purchasing replacement heifers or cows. Depending on which avenue the producer chooses, the carrying capacity of the ranch and weight of calf produced each year could be significantly affected. Furthermore, since purchasing replacements of the appropriate breed composition is the simplest way to maximize maternal heterosis (Weaber, 2010), the purchased replacement scenario is more likely to utilize crossbreeding to the greatest extent, meaning there will be an increase in weight of calf weaned by the ranch. In terms of mating decisions, there are multiple different options a producer could utilize depending on the way they choose to acquire replacement females. If they own large enough numbers, producers could allocate part of their herd for maternal matings to generate either purebred or crossbred replacement females. However, if the herd inventory is not large enough producers may choose to use a dual-purpose bull with a balance of both terminal and maternal genetics in order to raise both replacement quality females and males that are suitable for the feed yard.

Another option producers have is to focus strictly on terminal matings for feeder calves and purchase crossbred females bred with an emphasis on maternal qualities as replacements. Alternatively, producers could purchase purebred replacements, but the main consequence is maternal heterosis will not be realized (Ritchie et al., 1999). A more thorough discussion of the advantages and limitations of a terminal crossbreeding system is included in the subsequent Review of Literature.

Even though the benefits of crossbreeding (heterosis and breed complementarity) are well-documented (Gregory et al., 1965; Cundiff et al., 1974; Cundiff et al., 1992), many producers are moving toward or currently operate straight-bred Angus herds. The National Association of Animal Breeders (NAAB) reported Angus semen accounted for about 65% of domestic semen sales (NAAB, 2017). A survey conducted by Beef Magazine, Rutherford (2014), reported 51.3% of its readers operated straight-bred British (Angus or Hereford) herds, and 66.8% of respondents last bull purchase was Angus. When asked if they plan to change their cowherd's genetic profile, of the producers who do plan to make a change, 51% say they will increase the amount of British genetics.

These observations are not presented in an attempt to reduce or prevent the use of Angus genetics, rather they are intended to demonstrate the extent to which producers are trending toward straight-bred cowherds. This trend could be stimulated by several different factors including, the desire for a simplified breeding program, belief that straight-bred herds result in more consistency, greater availability of Angus expected progeny differences (EPDs) and a larger carcass database, and the desire to produce cattle within the parameters of branded beef programs like Certified Angus Beef (CAB) (Gosey, 2005).

In regard to how replacements are acquired there are two approaches, a producer can buy or raise them. Further management decisions include the type of breeding system they wish to utilize and the breeds to incorporate into that system and selecting the correct breeds relative to the production environment. All of which have implications on the resulting progeny, uniformity of the calf crop, the allocation of feed resources, and cow herd efficiency; which will be discussed in contents of this document.

REVIEW OF LITERATURE

Crossbreeding

Breed differences

Maternal and terminal traits are often antagonistic of one another (Weaber, 2015). When a bull is strong in terminal traits, he is most likely weaker in maternal traits and vice versa. When a producer selects bulls with an emphasis on maternal traits often the result is less genetic pressure for growth and carcass traits (Cundiff et al., 1993; Weaber, 2015). This antagonistic relationship stems from differences across breeds. British breeds (e.g., Angus, Hereford, Shorthorn, etc.) are historically known for their maternal capabilities (Spangler, 2014). They are typically more moderate in terms of growth, lactation and frame size, they are easy fleshing, have a higher carcass fat composition, and reach puberty at a younger age. Recently, British breeds have shifted toward higher growth and lactation potential (Spangler, 2014). Continental breeds (e.g., Limousin, Charolais, Chianina, etc.) are more terminal-oriented, being later maturing, heavier muscled, leaner, larger in mature size and producing less milk. Simmental, Gelbvieh and Maine-Anjou breeds are also Continental cattle, but have a higher lactation potential, moderate age at puberty, and a relatively large mature size. It should be noted that differences also exist within each of these breeds relative to maternal and terminal traits.

Heterosis

Heterosis is a valuable tool for producers and comes in different forms. Bourdon (2000) explains that retained heterosis is the increase in performance of crossbred progeny relative to that of its purebred parents. Another predominant form is maternal heterosis, which is the increase in production of a cow above that of the average of her parent breeds. Advantages of maternal heterosis are seen in maternal ability, reproduction, longevity, calf survivability, weight of calf weaned and younger age at puberty. Paternal heterosis is similar to maternal heterosis in that it is the genetic advantage, provided by the sire; benefits are also seen as increased bull fertility (Plank et al., 2013).

Breed Complementarity

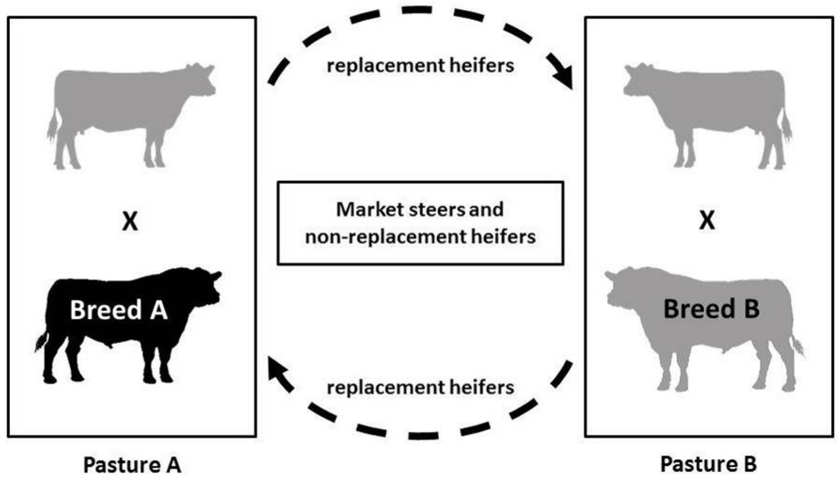
Breeds are complimentary to each other when one breed excels in certain traits the other breed does not and vice versa. If a successful mating is chosen the resulting progeny offer greater levels of performance in more traits than their straight-bred parents (Weaber and Spangler, 2013). Essentially, one would be using the strengths of one breed to offset the weaknesses of another (Gosey, 1991). Weaber and Spangler (2013) provide an example of the usefulness of breed complementarity in terms of matching cattle genetically to their environment and the resulting progeny to the marketplace. In the situation of a herd composed of crossbred Angus-Hereford cows mated to Charolais bulls, the crossbred cow offers the maternal capability along with carcass quality advantages while the Charolais bull will increase growth and carcass yield of his progeny.

Common Cross-breeding Systems

Two-breed rotation:

As seen in Figure 1-1, a two-breed rotation breeding system begins with the mating of two different breeds, sire breed A x dam breed B, creating a first generation crossbred (F_1). The resulting heifer progeny are then mated to the opposite of their sire breed, B x (AxB) and this will continue for the rest of her productive life.

Figure 1-1. Two-breed rotation



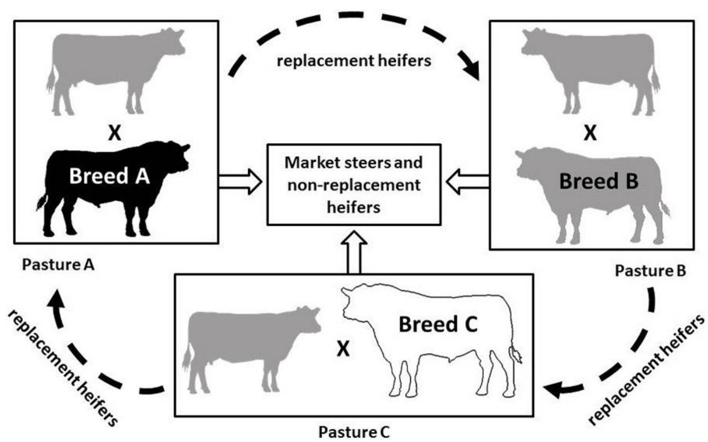
From Plank et al. (2013)

To effectively implement a two-breed rotation a minimum of two breeding pastures are required, one with sire breed A and the other sire breed B. Since this system is generally designed to produce replacement females from within herd, emphasis of selected traits for both bulls and heifers should be placed on the correct milk production potential relative to production environment, mature size (to ensure there is similarity among the produced replacements), structural correctness and udder quality; however, growth and carcass traits should not be overlooked. Birth weight, calving ease and calving ease maternal are also important in both bulls and heifers to avoid calving difficulty. Expected heterosis capture in a two-breed rotation is approximately 67% of maximum and increases weight of calf weaned per cow exposed by 16% (Gosey, 1991). The importance of the measure of weight of calf weaned per cow exposed is that it reflects cow herd reproductive efficiency in combination with milk production and preweaning growth potential of the calves. This value combines the percent calf crop weaned with weaning weight of the calves relative to the number of females exposed to breeding (Radunz, 2013).

Three-breed rotation:

A three-breed rotation is similar to a two-breed rotation, but simply incorporates a third, unrelated breed. The objective is to maximize heterosis by breeding each female to a sire that she is the most distantly related to. To better illustrate the system, Figure 1-2 is provided below.

Figure 1-2. Three-breed rotation



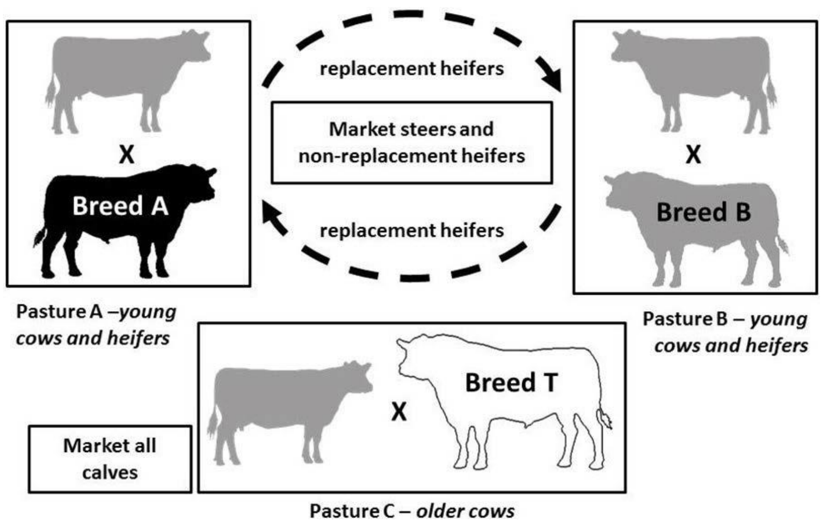
From Plank et al. (2013)

Each generation will continue to be mated to the same sire breed for the rest of their productive life. A drawback of this system is it can be difficult to find three breeds that are similar in size and milking ability. When crossbreeding and keeping replacements, selection emphasis should be placed on complimentary traits that allow the females to be an ideal match for the production environment (Weaber and Spangler, 2013). As shown by Cundiff et al. (1993) there are differences in production potential of the various breeds of cattle. NASEM (2016) outlines the breed adjustment factors for maintenance due to differences in production potential among breeds. The availability of ranch resources would be a large determinant of the correct combination of breeds used in the system. According to Plank et al. (2013) and Gosey (1991), larger herds are better suited for a three-breed rotation since more cows are required to justify using three different sire breeds. Due to the added complexity of the system, increased management and record keeping becomes a factor since at least three breeding pastures are required, or AI must be used. In time, this system will result in heterosis stabilizing at approximately 86% of maximum, and weight weaned per cow exposed is expected to increase by about 20% (Plank et al., 2013).

Rotational terminal:

This system essentially combines the use of a two- or three-breed rotation system to produce replacement females but incorporates a terminal sire on the mature females (Figure 1-3). Approximately 45% of the cow herd, usually the younger females, is used to produce replacements, while the remaining 55% of the cows, usually more mature females, produce terminal offspring where both males and females are intended for slaughter. The rotational herd is typically comprised of maternal breeds such as Hereford and Angus. Those F_1 replacements are typically kept in the rotational system until the age of 4. Since they are younger and due to selection should be genetically superior to older cows, they are better suited to make the next generation of replacement females (Greiner, 2009b). Another reason is it allows time for the cows to mature to decrease the rate of dystocia sometimes associated with terminal sires. After age 4, the F_1 females are moved to the terminal sire component of the breeding system.

Figure 1-3. Rotational terminal



From Plank et al. (2013)

In a rotational terminal system, heterosis has been shown to increase weight weaned per cow exposed by approximately 21% (Gosey, 1991; Weaber, 2010). The calves sired by the terminal sire benefit from maximum heterosis, while the calves produced in the rotational herd still realize the benefit of maternal and individual heterosis since all females are crossbred, although this added benefit is slightly diminished since a greater proportion of their pedigree favors one breed (Greiner, 2009b). Since 45% of the herd is in the rotational system producing replacement females, and the other 55% generating only terminally-bound calves (Gosey, 1991), of the calves marketed at weaning, 70% are a result of the terminal sire mating(s) b, while 30% are male progeny from the rotational system (Gosey, 1991). All females from the rotational herd are developed as replacements.

There are a few difficulties in terms of management with a rotational terminal system. First, unless AI is used, a minimum of three pastures are required. Two breeding pastures are needed for the rotational portion of the system. Then a third pasture is required for the terminal sire component of the system. Another challenge is that the group of cattle to be marketed could lack uniformity. This challenge results from approximately 30% of the marketed calf crop originating from the maternal mating to produce replacement females, while the other 70% is a product of a terminal mating (Gosey, 1991). Third, less selection can be performed on the retained females. This results from the necessity to retain the majority of heifers produced in order to maintain herd size. Finally, given the number of pastures and the number of cattle required it is also difficult to implement a rotational terminal system on herds small than 100 cows (Greiner, 2009b).

Composite breeding systems:

Composite breeding systems are very simple in their approach and are as easy to manage as a straight-bred system. A composite is the combination of typically 2 or more breeds of cattle, where the benefits of both heterosis and breed complementarity are realized (Gosey, 1991; Ritchie et al., 2002). In order to maintain optimum heterosis, the crossbred females are bred to bulls of the same combinations of breeds. Consequently, it is a simple system that requires only one breeding pasture and replacement females do not need to be identified by sire breed (Gosey, 1991). The more breeds that are incorporated into the composite, the greater percentage of the maximum heterosis is retained in the offspring. Composites made up of 2, 3 or 4 breeds are expected to retain heterosis at 50%, 67% and 75% of maximum, respectively, and increase weight of calf weaned per cow exposed by 12%, 15% and 17%, respectively (Weaber and Spangler, 2013). Depending on the number of breeds used composite systems may not offer the same advantage in heterosis as rotational systems, but they do offer a greater opportunity to use complementarity. Composite systems allow breeders to select breeds of cattle with considerable variation in size, milk production, growth and carcass merit, and combine them to make a crossbred that is an ideal fit for the available feed resources and environment. Furthermore, since management is similar to a straight-bred system, it is much easier for small herds to adopt and gain the benefits of heterosis and complementarity (Gosey, 1991).

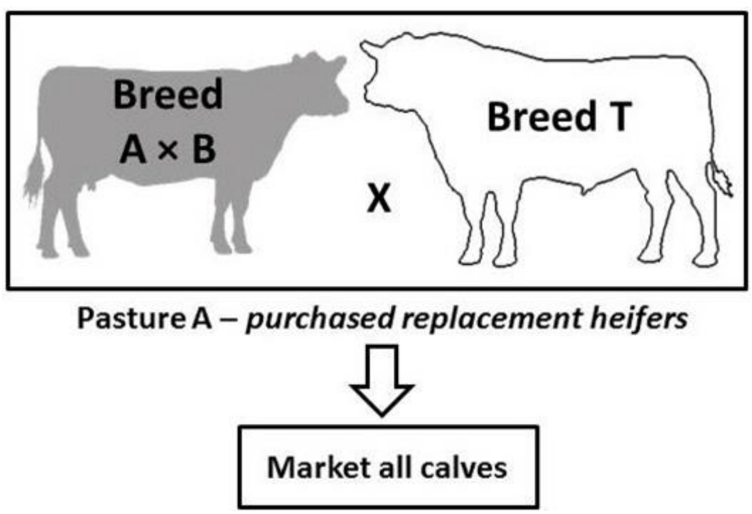
Composite systems allow the herd to be as large or small as desired, but to prevent inbreeding there must be a composite population of at least 500-1000 cows to produce unrelated seedstock (Ritchie, 1998). Smaller herds would need to purchase a sire unrelated to the herd from other breeders who are creating the same composites or composites of the correct breed composition for that operation.

Another advantage associated with composite systems is found in the use of hybrid sires. Not only are the cows crossbred but the bulls are as well which captures the benefits of paternal heterosis. Compared to purebred sires crossbred bull have been documented to show increased libido, semen quality, and mating vigor (Gosey, 1991).

Purchased replacements with a terminal sire:

In this simple, one-pasture system, as illustrated in Figure 1-4, F_1 females would be purchased to capitalize on maternal heterosis, then bred to a terminal sire of a third, unrelated breed to also increase the growth and carcass merit of the calf crop. That, in combination with the simplicity of this system, make it an excellent choice to maximize heterosis and breed complementarity (Weaber and Spangler, 2013). A breeding program such as this can increase weight of calf weaned per cow exposed by 24-28% (Massey, 1993; Weaber, 2015).

Figure 1-4. Purchased replacements with a terminal sire



From Plank et al. (2013)

Defining Efficiency

Considering the scope of the cow-calf sector of the beef industry, efficiency is not easily defined. In the livestock industry, there are two primary ways of defining efficiency: biological efficiency and economic efficiency which are two concepts that can be difficult maximize in unison (Radunz, 2013).

The simplest definition of a cow that would be considered biologically efficient is one that can produce a calf each year that she remains in the herd (Jenkins and Ferrell, 2002). While the simplicity of that definition seems easy to achieve, there are many variables that can affect this, and this method is not the only way of measuring efficiency. According to Dickerson (1970), efficiency in animal production is measured by the total animal product produced from females and their progeny to the total cost. There are three basic functions that determine the cost to produce animal products, the first being female production, the second being reproduction, and the third growth of the young (Dickerson, 1970). Another similar definition is that the most efficient cow can repeatedly produce a calf with the growth and carcass genetics most valued in the marketplace, and offer the highest level of milk production without sacrificing reproduction (Johnson et al., 2010). The emphasis on overall efficiency (economic and biological combined) in the beef industry is because, relative to other species, the production of beef can look much less efficient (Ritchie, 2000). Dickerson (1984) estimated that approximately 5 or 6% of the life cycle energy expended in beef production is used for deposition of body protein in market animals. Relative to pork and poultry, the feed energy input per unit of meat protein output is significantly higher in beef production. The advantage beef cattle have is the ability to convert roughages and crop residues that pork and poultry cannot utilize into beef. About 90% of the total life-cycle feed energy comes from pasture, harvested forages and grain by products (Ward et al., 1977). It should be noted the beef industry has shown significant improvement in terms of efficiency through producing more beef with fewer cows (Radunz, 2013).

Biological efficiency in the cow-calf sector can be measured in multiple ways. One measure is the ratio of calf body weight (BW) weaned in relation to the BW of the dam (Johnson et al., 2010). Unfortunately, this measure has a few flaws, namely the lack of direct accounting for feed consumption, milk production, and reproductive efficiency. The ability to reproduce is the most important contributor to cow efficiency on the ranch (Johnson et al., 2010). Other measures of biological efficiency are weight of calf weaned per cow exposed per pound of cow weight, and weight of calf weaned per cow exposed per unit of feed energy consumed (Ritchie, 1995). Another, more simple, measure of herd efficiency is weight weaned per cow exposed, since it includes reproduction in the ratio along with weaning weight of the calf crop (Johnson et al., 2010; Radunz, 2013).

While both biological and economic efficiency are related, if one were to compare the two types of efficiency from the standpoint of input/output, biological efficiency would be defined as the ratio of feed consumed to beef produced and economic efficiency is the relationship of dollars spent to dollars returned. For example, a cow may be considered biologically *inefficient* due to higher feed energy inputs per unit of production (i.e., weight of weaned calf). However, she may be considered economically *efficient* if feed costs are low enough to justify the energy required to produce said calf (DiCostanzo and Meiske, 1994). From an economic standpoint, efficiency is achieved when a ranch can wean the highest percentage of the calf crop, at the heaviest weight possible, with the lowest cost. Biologically speaking, efficiency depends on the interaction of genetics and environment (Johnson et al., 2010). For a cow to remain biologically efficient, the nutritional requirement of the cow must match available feed resources, allowing maximum milk production to facilitate maximum growth in the calf without causing reproductive failure. If feed resources exceed the requirement of the cow, excess intake energy will be deposited as adipose which is an inefficient process (Jenkins and Ferrell, 1994). Which leads to the different biological types of cows and their corresponding maintenance requirements. Ritchie (1995) explains high maintenance cows as being high input - high output. They have a high milk production potential, visceral mass, lean body mass and low body fat mass. Whereas low maintenance cows reside on the other side of the spectrum, being low input - low output with a low milk production potential, visceral body mass, lean body mass and high body fat mass.

Cow size and milk production play a role in efficiency, especially considering marketing plans, crossbreeding strategy, environment and management program (Notter et al., 1979a, b). A study conducted by Van Oijen et al. (1993) compared the difference in economic and biologic efficiency of cows of varying levels of milk production. Cows were placed in three lactation groups based on breed: Hereford-Angus (low; L), Red Poll-Angus (medium; M), and Milking Shorthorn-Angus (high; H). All groups had similar genetic potential for growth and mature size. Biological efficiency was defined as the ratio of calf weight to total feed energy required. Economic efficiency was defined as the ratio of dollars output to dollars input. Results showed that cows of the L group were the most efficient both economically and biologically to weaning and slaughter. The M and H groups showed equal efficiencies. In contrast, Freking and Marshall (1992) reported a strong correlation between increased milk production and improved biological efficiency to weaning. It should be noted this study was conducted on first calf heifers which had not yet reached peak milking ability, which could explain the difference between the two studies. Deciding what level of milk production a cow should exhibit is not a one size fits all decision. Paying close attention to growth and milk production ability, while matching it to the available resources is the best way to generate efficient cows (Greiner, 2009a).

In a study by Jenkins and Ferrell (1994), nine different breeds were evaluated for their biological efficiency on a range of dry matter intakes (DMI). Their findings showed that breed type played an important role in biological efficiency. When fed at lesser DMI, breeds of lower genetic potential for milk and growth (Angus, Red Poll, and Hereford) were more biologically efficient due to greater reproduction rates when compared to larger breeds. In contrast, when cows were fed at greater DMI levels, larger breeds with greater genetic potential for milk and growth (Gelbvieh, Charolais, Braunvieh, Simmental, Pinzgauer, and Limousin) were able to exceed their reproductive energy needs and convert additional energy to milk which resulted in more weight of calf at weaning. However, when the smaller British breeds are exposed to greater DMI levels they could not convert additional energy to milk. Instead energy was stored as fat which is an inefficiency. In general, these results hold true in regard to breed type, with an understanding that there is some variety in maintenance requirement and production potential within breeds of cattle.

The proper cow size for a given operation can also be affected by market conditions. There are a number of factors that affect the prices of calves at weaning, one being that feeder cattle buyers are more likely to buy calves that are larger-framed and heavier-muscled (Schroeder et al., 1988). Price is also affected by factors such as weight, horns, color, lot size, condition, uniformity, and health (Schroeder et al., 1988). In the 1970's, Continental cattle were imported from European countries. This importation was a result of the packing industry incentivizing producers to produce cattle with heavier carcass weights and the fact that larger cattle with more growth potential are more efficient in the feedlot (Ferrell and Jenkins, 2006). Because there was a push for heavier carcasses, producers began to use these Continental cattle because they offered the growth and carcass traits desired. As a result of selecting for more weight at weaning and post-weaning, cow size also increased, which depending on available feed resources could have negative effects from a cow calf biological efficiency standpoint (Kelley, 2006).

Buying versus raising replacements

A major cost to producers in the cow-calf sector is how they acquire suitable replacement females to add to the herd (Schulz and Gunn, 2014). Since 1990, the culling rate has been around 14.1%; meanwhile, the typical replacement rate is approximately 17.8% (Ringwall, 2012). Since then, CHAPS 2000 annually reports a five-year average culling and replacement rate which are 13.2% and 14.7%, respectively (Tisor, 2017). Replacement females represent a significant portion of the herd each year, and if not acquired in an economical fashion, can represent a significant expense.

There are a few different approaches in acquiring replacement heifers. Cow-calf producers could retain heifers raised within their own herd, purchase open females or they could purchase bred females. Each approach offers advantages and disadvantages which producers must consider before they can make a decision.

Literature by Willett and Nelson (1992) and Schulz and Gunn (2014) described some of the potential advantages of a producer who keeps and develops their own heifers. If a producer's breeding program consists of multiple generations of females selected for the traits they deem most important, they have the opportunity to make females that genetically fit their program better than anything they could buy. The heifers are acclimated to the climate they will be expected to perform in and the producer could potentially operate a closed herd which is beneficial for disease management. It also gives the producer more information on the background of the heifers since they are more likely to be familiar with the history, disposition, growth and phenotype of each female. Lastly, in some instances there is opportunity to develop retained heifers cheaper than it would be to buy bred replacements.

When retaining replacement females there are decisions that need to be made beginning at weaning. Heifers would generally be sorted into two groups; those of replacement quality are kept for development and the remaining heifers are sold. In general, when selecting females to develop, keeping heifers that are heavier at weaning could mean they are older and may reach puberty earlier (Bolze and Corah, 1993). Also, the dams of the heifers born early in the calving season could be more fertile which means their daughters may share that same trait (Troxel and Gadberry, 2011). Further selection criteria places emphasis on heifers whose dams that have good udder and teat structure, calve easy and have a quiet disposition.

One must also consider how many heifers to retain in order to have the right number of bred females to replace any culled females. If one were to assume that 50% of the calf crop is heifers, the producer needs to retain nearly a quarter of their herd size to meet the 14.7% replacement rate. A ranch must keep and develop 10 - 15% (Sprott and Troxel, 1988) more heifers than will be needed to account for potential health, reproduction, or other obstacles that may limit suitability of a heifer to become a productive member of the herd. Thus, producers may need to breed the entire cow herd to bulls with an emphasis on maternal traits to generate an adequate number of replacement candidates. These calves could also compromise the terminal value of the calf crop. How much production is lost from marketing progeny that are lighter at weaning as a result of matings intended for replacement production? Not only are the steers likely to be lower performing compared to terminal cross contemporaries, but the lower quality females that did not make the replacement pen also negatively affect the quality of the group.

A producer must also understand the implications raising their own replacements can have on how resources are allocated. Since replacements are developed on the ranch, a rancher could unintentionally be sacrificing marketable product due to part of the ranch resources being devoted to developing females that are not rearing a calf to sell. If bred females were purchased the ranch resources could support more producing cows with a calf at side. Furthermore, the ranch could potentially produce more weight of weaned calf since the entire herd would have a calf at side.

From the standpoint of labor and feed resources, this is an area where purchasing bred replacement is advantageous. When buying bred heifers, they have already been developed to approximately 80% of their mature size (NASEM, 2016). Since there is no development of young heifers on the ranch, more resources can be used for mature, producing cows. It should be noted that producers could purchase open heifers and still garner the benefit of heterosis and breed complementarity. However, doing so places them in the same situation of retaining replacements where they are having to dedicate resources to females that are not currently raising a calf.

Purchasing bred replacement females can also have a positive impact on the number of bulls required and the traits those bulls are selected for. Since there is not a need for a calving ease sire to cover heifers, the producer may find fewer bulls are necessary and selection emphasis can be placed on strictly terminal production. This strategy should result in production of a more uniform calf crop and more post-weaning merit associated with terminal genetics. Genetically, a producer could more rapidly adapt their herd to changing market signals since they could potentially source heifers that are superior to what they could raise or would take too much time and management to produce their equal with a complex breeding system (Schulz and Gunn, 2014).

Although purchasing crossbred replacements is the fastest and simplest way to benefit from maternal heterosis, it is not the only system that uses crossbred females. Rotational terminal and composite systems also offer this advantage. However, purchasing crossbred females may be preferred since the entire cow herd can benefit from maternal heterosis as opposed to a portion of the herd being dedicated to purebred females to generate crossbred replacements. Improvements in cow longevity by 16.2% are observed when operating with crossbred females, which would decrease the number of replacements needed each year (Cundiff and Gregory, 1999). A 14.7% replacement rate means the average cow age is 6.8 years old (Tisor, 2017). If cow longevity is increased by 16.2%, the average cow age increases to 7.9 years old which results in a 2.1% decrease in replacements purchased each year. Reducing the replacement rate can also impact weaning weights of the calves. For example, the American Angus Association adjusts weaning weight of calves produced by cows 2-4 years of age up by a certain amount based on the age of the cow (American Angus Association, 2018). This is because calves from young cows are not as heavy at weaning as calves produced by mature cows due to the fact younger cows are still developing (Rumpf and Van Vleck, 2004). If the herd is composed of a greater number of mature cows, a larger number of cows are producing milk at their maximum potential and thus weight of calf produced would increase. However, since this essentially decreases the generation interval, genetic progress could be decreased as a result.

Purchasing replacement females is not a problem-free approach. Implementing such a program would require a heifer of a specific breed composition that could be more difficult to acquire and be subject to differential pricing at the time of purchase. Since replacements are purchased, introduction of new heifers could expose the herd to potential disease threats. Lastly, it is important to make sure the replacements match the environment they will be expected to work in (Cleere, 2006; Schulz and Gunn, 2014). If cattle do not match their production environment the result could be reproductive failure or cows becoming too fat as they cannot produce enough milk relative to the resources available (Jenkins and Ferrell, 1994; Johnson et al., 2010).

Neither approach, raising versus purchasing replacement females, is perfect. Users must be able to identify the advantages and disadvantages of each system, then decide which is the best fit for a particular operation. Understanding how different breeds of cattle fit relative to various environments and using that knowledge to create a crossbred animal that through heterosis allows optimal production in a particular climate can be very influential in the success of an operation. Relative to the pork and poultry industries, the beef industry still has room to grow in terms of producing terminal bound progeny from crossbred females and terminal sires (Weaber, 2015). Conventional breeding systems can be difficult for some producers to implement due to the increased management associated with such systems (Gosey, 1991). Purchasing crossbred replacements is an alternative that could allow producers to maximize the benefits of heterosis and breeding complementarity with the simplicity of managing a straight-bred operation.

CHAPTER TWO

ANALYSIS OF THE IMPACT OF DEVELOPING STRAIGHT-BRED ANGUS REPLACEMENT FEMALES VERSUS PURCHASING BRED, CROSSBRED REPLACEMENT HEIFERS ON PRODUCTION PARAMETERS

Introduction

In the US, beef cow herds are largely composed of straight-bred British cattle. According to a survey conducted by Beef Magazine, 51.3% of respondents run straight-bred British cows and 17.7% own British crossbreds (Rutherford, 2014). Also, 66.8% of respondents' most recent bull purchase was a straight-bred Angus bull (Rutherford, 2014). There are a couple conclusions that can be drawn from these data. First, branded beef programs have incentivized producers to move toward Angus-based cattle (Zimmerman and Schroeder, 2011), and second, the majority of beef producers do not utilize crossbreeding and thus forego benefits associated with heterosis and breed complementarity. There are multiple reasons that could underlie the limited adoption of crossbreeding. According to Gosey (1991), crossbreeding systems are difficult for many breeders to utilize due to the herd size, number of breeding pastures, breeds, and sire breeds of females required by some crossbreeding systems. Many of the beef herds in the country represent units too small to effectively utilize some crossbreeding systems (Gregory and Cundiff, 1980). The average herd size in the United States is 40 cows and the majority of these herds serve as supplemental income to off farm jobs (USDA, 2018a). Even herds with enough cows to use a crossbreeding system may find these systems difficult to manage (Gosey, 1991).

A common approach to acquiring replacement females in the cow-calf sector is to retain heifers raised within the herd and develop them into bred females. Some cattlemen can raise a replacement female that is of greater quality both genetically and phenotypically than what they can buy (Schulz and Gunn, 2014). Furthermore, it is easier for producers to manage disease, it is potentially cheaper for a producer to develop their own females, and the producer is familiar with the cattle and their disposition (Schulz and Gunn, 2014). However, when raising replacements there can be an inability to effectively combine the advantages of both maternal and terminal heterosis (Whittier, 2001). Furthermore, if replacements are home-raised they are displacing resources that could be allocated toward cows that will produce a calf. Elimination of the heifer development component of an operation would allow the producer to focus on other aspects of their operation and better align their breeding program with industry demands (Whittier, 2001).

Depending on the year, a producer could potentially buy replacements cheaper than they could raise them, and they may be able to purchase animals of higher quality than what they could raise. Purchasing is a way for producers to circumvent the required management and costs associated with developing replacement heifers. Producers could increase herd size or change their breeding strategy more quickly by purchasing bred females of their desired breed composition and mate them to a bull that would complement the females to produce the desired offspring. Purchasing bred replacement females allows a producer to maintain a herd of females that will produce a calf to sell each year (Schulz and Gunn, 2014). This strategy would provide resource flexibility and allow for more cows, and consequently, more calves available for sale. If a producer chose crossbred females and used a terminal sire, on average the calves would have a significant advantage over straight-bred calves. The combined effects of maternal and terminal heterosis yields a 20-28% increase in kg weaned/cow exposed/year (Spangler, 2007; Weaber, 2015). In a crossbreeding system where F_1 females have been mated to a terminal sire of a different breed, the expected advantage is 23.3% (Gregory et al., 1965;

Cundiff et al., 1974). In this system, 8.5% of the heterosis advantage comes from heterosis for individual traits (Gregory et al., 1965) and 14.8% is derived from maternal heterosis from the crossbred cow (Cundiff et al., 1974). This demonstrates the importance of both maternal and individual heterosis, but most importantly the benefit of the crossbred cow.

Our hypothesis is that purchasing crossbred replacement females and breeding them to a terminal sire would allow for a ranch to operate with more cows, and with greater heterosis, produce more saleable product than if they raised straight-bred replacement females.

Materials and Methods

Weight assumptions

The two systems selected for comparison were: 1) a straight-bred Angus-based cow herd that retains home-raised females and breeds them to an Angus sire (HR), and 2) a crossbred Hereford x Angus-based cow herd that purchases bred F_1 Hereford x Angus replacement heifers and breeds them to a terminal sire (PR). Straight-bred calf weaning weight (WW), weaning percent of cows exposed, kg weaned/ cow exposed, and percent of cows calving were sourced from the Livestock Enterprise Analysis (FINBIN, 2017). Home-raised and PR cow weights were considered equal and calculated from the straight-bred calf weaning weight (FINBIN, 2017) assuming the calves weighed approximately 46% of the dam’s body weight at weaning (NASEM, 2016). Thus, resulting cow weights were 537 kg for both HR and PR cows. Cow weights were considered the same, assuming the rancher would purchase females that match the environment meaning cows of the same weight and mature size regardless of breed type.

Reproduction assumptions

This simulation is based on a straight-bred herd size of 100 cows, with a replacement rate of 14.7% (Tisor, 2017), (Table 2-1). As such, it was assumed that 15 replacement females would be required each year and enough heifers needed to be retained to meet the herd replacement needs after the first exposure to artificial insemination (AI). Diskin and Sreenan (1980), reported that conception rates in beef heifers after their first exposure to AI was 58%. Lamb et al. (2006), observed a 56% conception after a single AI in heifers across four synchronization protocols. In a study conducted by Busch et al. (2007), where a variety of fixed time AI protocols were utilized, the observed first time AI conceptions rates ranged from 41-64%. In our simulation, it was decided that 58% would be used as the first time AI conception rate since it was derived from heifers where AI protocol was not being tested, and the heifers were inseminated on standing estrus as opposed to timed-AI. Thus, 25 heifers would need to be developed to achieve 15 pregnant heifers after first AI. With an assumed 88% overall pregnancy percentage for the heifers (Lardner et al., 2014), 22 of the 25 heifers will be pregnant after the breeding season. This would result in 7 extra bred females available for sale at mid-gestation. The remaining 3 extra females would be culled at pregnancy check. In order to maintain a similar stage of production and metabolizable energy (ME) requirements between the two system, it was decided that since one could purchase females to calve in a certain time frame, the HR females retained also need to calve within a certain time frame. It should be noted there are other options in terms of how many females to keep depending on the goals of the ranch.

Since there will be more bred females at the end of the breeding season than necessary, extra bred females would be sold at mid-gestation, about the time one would be purchasing bred replacements. Our scenario assumes that after the females were exposed to AI they would then be turned out with a “clean up” sire for 60 days. Pregnancy diagnosis would occur 65 days after removal of the bull (Bormann et al., 2006), and any open females would be immediately culled.

Energetic assumptions and calculations

The ME requirements of the HR heifers were calculated in segments: weaning to d 28, d 29 to breeding, and breeding to mid-gestation. All ME requirements were calculated using the Nutrient Requirements of Beef Cattle model (NASEM, 2016). The first phase (weaning to d 28) is based on a fence-line weaning strategy where females share fence line contact with dams. Weaned calf performance can vary with a fence-line weaning system. Bailey et al. (2016) demonstrated this variability with calves subjected to three treatment groups, 1) dry lot weaning + complete visual and auditory separation from dams, 2) pasture weaned + fence line contact with dams, 3) pasture weaned + fence line contact with dams + supplemental feed. Both fence line treatments lost weight during the 28-d weaning period. In our comparison we chose to use a pasture weaned + fence line contact with dams. It was decided to consider ADG during the 28-d weaning phase to be zero. The ME requirement was calculated for weaning to d 28 based on a 10-year average calf weaning weight of 250 kg (FINBIN, 2017). Adjustment factors of 1.028 for steers and 0.972 for heifers were calculated based on average steer and heifer weights reported by Tisor (2017). The adjustment factors were multiplied by the average WW of the calves in the livestock enterprise analysis (LEA) to arrive at an average heifer and steer shrunk body weight (SBW) of 240.4 kg and 254 kg, respectively.

From d 29 to breeding, heifers were assumed to be developed on native range grass/hay (8.3% CP, 1.04 Mcal/kg net energy for maintenance (NE_m), and 0.48 Mcal/kg net energy for gain (NE_g), and a range cube supplement (3.26 Mcal/kg ME; Table 2-2). Heifers would be developed to the traditionally recommended weight of approximately 65% of mature weight in order to facilitate proper conception rates (Patterson et al., 1992). Simulated developing time frame was 223 days, with beginning weight = 250 kg; end weight = 364 kg; and average daily gain (ADG) = 0.51 kg/d.

The third stage was from breeding to mid-gestation. Since mid-gestation is when the replacements would be purchased, the calculation of feed resource requirements ended at that timepoint. After that time point, feed resources would be utilized by replacements regardless of whether they were raised or purchased. Assumed gestation length was 280 d (NASEM, 2016), simulated beginning weight at breeding = 364 kg (approximately 65% of mature size), end weight at calving = 448 kg (approximately 80% of mature size) (NASEM, 2016).

To determine the total amount of ME required to maintain a cow throughout the year using the NRC Model , the NE_m was determined and converted to ME by way of a quadratic equation (NASEM, 2016). This conversion was done separately for the HR and PR cows to account for any possible differences in maintenance requirements. Since the crossbred cows are bred to a terminal sire in the simulation, the resulting calves would be heavier at birth, as Continental sires commonly used as terminal sires have greater birth weights than British cattle (Cundiff et al., 1998). This increase causes an increase in cow energy requirements according to the NRC model (NASEM, 2016) maintenance adjustment factors for beef cows.

Marketable products assumptions

To determine the difference in WW between the HR system and PR system, we used LEA data for the straight-bred values for number of exposed cows calving, weaning percent/cow exposed, kg weaned/cow exposed and calf WW (94.6%, 89.2%, 220.4 kg, and 247.2 kg, respectively; (FINBIN, 2017). The amount of marketable weight at weaning produced in the HR system the weight was divided between steers and heifers. This is because 25 heifers are retained as replacement candidates, thus, there are fewer females to sell than there are males. Male calves tend to have an advantage in pre-weaning weight and this advantage should be accounted for (Rumpf and Van Vleck, 2004). Resulting shrunk body weights of the steers and heifers were 254.0 kg and 240.4 kg, respectively. An assumed herd weaning percent of 89.2% (FINBIN, 2017), a herd size of 100 cows, and the retention of 25 females as replacements, translates to 45 steers and 20 heifers available for sale. In the purchased replacement system, the advantage gained through heterosis was assumed to result in an increase of 1% in number of exposed cows calving (Cundiff et al., 1992), 2.5% in weaning percent/cow exposed (Cundiff and Gregory, 1999), and our calculations showed an 8.8% increase in kg weaned/cow exposed, and 6.2% increase in calf WW. The percentages and weights for each of those metrics are 95.5%, 91.4%, 240.2 kg, and 262.8 kg, respectively, in the simulation. The advantage in kg of calf weaned/cow exposed has been documented to be 23.3% when mating crossbred cows to a terminal sire of a different breed type (Gregory et al., 1965; Cundiff et al., 1974). Since an increase of 23.3% results in a significant increase in weight, it was decided that an increase in kg would be used instead of a 23.3% increase. Data from Cundiff and Gregory (1999) showed an increase of 7.4 kg due to the advantage provided by the crossbred calf, and an 8.2 kg advantage provided by the crossbred cow for a total of 15.6 kg. These values were used as the increase in weight observed in the calves as a result of using crossbred cows and a terminal sire.

The HR system also produces marketable weight in the form of developed heifers, both bred heifers and open culls. Weights of those females were determined using an assumed ADG of 0.30 kg/d from breeding (364 kg) to calving (448 kg) (NASEM, 2016). This allowed for the calculation of the weight of cull heifers at pregnancy check. Bred heifers were assumed to be sold on a per head basis.

Economic Comparison

A comparison was conducted between to two systems (HR vs PR) using data from the LEA (FINBIN, 2017) and the Livestock Marketing Information Center (LMIC, 2018), to discover which scenario is more economically favorable. In the both replacement scenarios, the value of the weaned calves and open cull heifers/cows was derived from the LMIC (2018) data and replacement heifer value from the LEA (FINBIN, 2017). The same value was used for the bred replacement heifers purchase price in the PR system and the sale price for the bred heifers to be sold in the HR system. Cull sales of open heifers and cows was calculated using the average values reported in CO, WY, and MT, per kg of a 363-408 kg heifer and $/kg of lean cull cows in October 2017. The value of the calves at weaning was based on the average sale price for the months of September through November 2017 for cattle weighing 227-272 kg. Calves were divided by sex in order to account for potential differential pricing. Annual cow expenses were based on data from the LEA (FINBIN, 2017), where the value includes total direct and overhead expenses with an additional labor and management charge. Since the F_1 cows have a slightly higher maintenance requirement (NASEM, 2016), approximately 1.3% higher, an adjustment factor of 1.0068 was calculated to apply to the total cow cost to account for the increase in cow maintenance expense. This adjustment factor was based on the feed cost relative to the total annual expenses per cow. Since feed cost accounted for approximately 52% of the annual cost, increasing the feed cost by 1.3% results in the previously stated adjustment factor.

RESULTS

The purpose of creating this simulation comparison was to gain a better understanding of the implications of purchasing bred, crossbred replacement females and using a terminal crossbreeding system relative to maintaining a straight-bred cow herd that raises replacement females on the carrying capacity of the ranch and total kg of calf to sell.

Table 2-3 shows the number of heifers the rancher would need to retain and develop to meet the desired replacement rate if only keeping females that conceived to the first AI. An assumed 58% first service AI conception rate results in the need to keep and develop 25 heifers, which translates to 57% of the heifer crop.

The energetic cost of retaining developing a heifer from within the herd is substantial. Weaning to d 28 represents the beginning of developing a heifer into a replacement. During this time frame, predicted heifer ME intake was 10.8 Mcal/hd/d, total ME required for the period was 303 Mcal ME/hd (Table 2-4). Table 2-5 illustrates the simulated ME required to develop a heifer from D-29 to breeding. Predicted daily ME intake =15.09 Mcal/hd/d, and total predicted ME intake per animal for the period = 3,365 Mcal ME/hd. Simulated ME requirements for replacement heifers from breeding to mid-gestation are illustrated in Table 2-6. Total ME intake by bred replacements = 3,144 Mcal ME/hd for the period.

The ME requirement of an Angus cow is shown in Table 2-7. Resulting ME requirement was 8,783 Mcal/hd/yr. Table 2-8 consists of the ME requirement of a PR, which was calculated in the same manner. The PR cows have a slightly higher maintenance requirement of 8,900 Mcal ME/hd/yr.

Once the ME requirement was identified for all stages of production the total ME required for each system was determined. As shown in Table 2-9, the straight-bred HR scenario features 100 cows with a ME requirement of 8,783 Mcal/hd/yr, and the total ME for the cow herd was 878,300 Mcal ME. From weaning to d 28, the total ME necessary for 25 developing heifers was 7,574 Mcal ME. From d 29 to breeding, 25 developing females required 84,127 Mcal ME. In the period of breeding to mid-gestation, 3 of the heifers were culled at pregnancy check (September/October), and the total ME intake of the culled females was 2,016 Mcal ME/hd or 6,049 Mcal ME total. The remaining 22 bred females consumed 3,144 Mcal ME/hd or 69,152 Mcal ME total. Together, all stages of the straight-bred simulation would require 1,045,202 Mcal ME.

Following the calculation of the simulated straight-bred ME requirement, the number of PR cows the ranch could otherwise carry can be determined. Table 2-10 illustrates the PR cow ME requirement of 8,900 Mcal/hd/yr, which in turn results in 17 more PR cows that could be supported on the same energy resources used in the HR scenario.

The difference in cow herd productivity between the HR and the PR systems can be found in Table 2-11. Differences in total kg of saleable product produced in each system simulation is shown in Table 2-12. When sold at weaning the 45 steers and 20 heifers totaled 16,238 kg of marketable weight. Bred females average SBW at the simulated time of sale was 408.7 kg/animal or a total weight of 2,860.9 kg. The open cull SBW was 388.7 kg/animal or 1,166.1 kg total. Total marketable weight of females developed as replacements, but not retained is 20,265 kg. In comparison, the purchased PR simulation allows the producer to operate with 117 cows on the same resources. A herd weaning percent of 91.4% yields 107 calves, all of which are sold at weaning. Average calculated SBW at weaning was 262.6 kg, resulting in a total of 28,098.2 marketable kg. The resulting difference in production between the two systems is 7,833.2 kg in favor of the PR system.

The economic comparison between the two systems is divided into two segments: gross revenue (Table 2-13) and total expenses (Table 2-14), and is summarized in Table

2-15. The resulting difference in system income is $10,949 in favor of purchasing bred crossbred replacement females and breeding them to a terminal sire.

Discussion

There is more than one way a producer could approach determining how many heifers they would keep to develop as replacements. In this simulation we chose to keep enough heifers to facilitate meeting the required demand for replacements from heifers that conceived to their first AI service. Alternatively, a producer could only keep as many as they would need to meet the herd replacement rate; however, extra females would still be necessary to account for those that fail to become pregnant.

A producer does not necessarily have to purchase crossbred replacements to use a system like this. Straight-bred females could be purchased and the operation could still benefit from the advantage of running more cows, and through the use of a terminal sire, could increase weaning weights. However, the maternal heterosis advantage would not be captured since the cows are not crossbred; and maternal heterosis has been shown to be more impactful than individual heterosis (Cundiff and Gregory, 1999). Breeding of composites can also be a very useful alternative that offers the same advantages in terms of simplicity. The ranch only needs one breeding pasture and still benefits from heterosis and breed complementarity (Gosey, 1991; Ritchie et al., 2002). However, the added benefit of heterosis is not as great as using a crossbred female and a terminal sire (17% increase in weight weaned/cow exposed in a 4-breed composite versus 23.3% increase for crossbred females bred to a terminal sire) (Cundiff and Gregory, 1999). Additionally, if a producer were to raise their own composite replacements, there would be fewer producing cows and total weight available for sale would decrease.

When comparing the two systems from an efficiency standpoint, whether evaluating biological or economic efficiency there are benefits on both sides when purchasing crossbred replacements. We calculated overall efficiency to be the ratio of total costs to total product produced. Compared to a 100 animal straight-bred herd, purchasing crossbred replacements allows cow-calf operations to produce approximately 39% more kg of calf to sell on the same resources. Radunz (2013) indicated that while economic and biological efficiency are related, they are difficult to maximize together. By purchasing crossbred replacement females, a producer would be able to increase biological efficiency (increasing kg of calf weaned/cow exposed using the same resource base), as well as economic efficiency (i.e., more dollars generated per dollar spent).

Buyers typically have specific traits they are looking for in terms of physical characteristics (e.g., lot size, uniformity) of the cattle being marketed (Schroeder et al., 1988; Schulz et al., 2010). Buyers tend to prefer larger, more uniform lots of cattle that reflect the number of cattle that can fit in a truckload. It has been shown that it is more profitable to market cattle in lot sizes similar to the size of a truck load (Faminow and Gum, 1986; Schulz et al., 2010). Other factors such as breed, muscling, frame size, color, health, and horns also affect the price received (Schroeder et al., 1988; Schulz et al., 2010). Schulz et al. (2010), evaluated factors affecting feeder calf price in Kansas and Missouri. Data collected on approximately 84,000 cattle included factors such as frame, weight, color, sex, uniformity, muscling, horn status, and condition. Base price associated with breed, color, muscling and frame was Hereford, red, average muscling, and medium frame respectively. Some of the largest premiums were associated with traits including, black hides, heavy muscling, and British influence. Premiums were still garnered by cattle who were white/mixed color, large framed, or were a Continental crossbred. Gosey (2005) suggested that beef producers are trending toward largely Angus herds, due to the premium associated with black hides, British influence, uniformity and branded beef programs like CAB. Gosey (2005) also pointed out that in an effort to earn premiums in the sale barn producers have overlooked the advantages of heterosis and breed complementarity. In our comparison, we calculated that more kg of beef could be produced using purchased crossbred females bred to a terminal sire. Depending on the sire breed of choice there is still opportunity to garner black hided premiums and a better opportunity to be awarded premiums for muscling, and frame size.

It should be noted that in the economic comparison between the two systems, prices did not include any premiums or discounts. The reason being is purpose of the comparison was to show how generating more saleable weight on the same resources can affect ranch profitability. However, every situation will be different relative to the prices received. The same can be said about the price received for developed bred and open females, and the purchase price of purchased bred replacements.

The advantages of heterosis are well documented (Spangler, 2007; Weaber, 2015), yet crossbreeding is not utilized to its fullest potential. One of the main reasons behind cattle producers not utilizing heterosis and breed complementarity to a greater extent is that many crossbreeding systems do not fit into a common-sense ranch management plan (Gosey, 2005). According to USDA (2018b), the average beef herd size in the United States is 40 cows. Since some crossbreeding systems require at least

100 cows to operate effectively, herd size becomes a barrier to adoption for some producers (Gosey, 2005; Greiner, 2009b; Plank et al., 2013).

Other reasons for the lack of adoption of crossbreeding in the beef industry go beyond simple logistics. Daley (2006) suggests that there is a cultural bias that a purebred animal is superior to crossbred animals. This belief has been partially fueled by purebred breeders, breed associations and some traditional marketing outlets (Daley, 2006). Heterosis is also difficult to visualize, in that the lowly heritable traits such as longevity, age at puberty, conception rate, and morbidity are not easily observed. There have been instances where producers have failed when attempting to crossbreed due to the lack of a proper long-term strategy, which has led to a perception that the result of crossbreeding is a lack of predictability. Making correct mating decisions is extremely important and can have large effect on the cowherd from the standpoint of calf crop uniformity and how well the cows match their production environment. Often focus gets placed on single traits like frame, growth or carcass traits, all of which are highly heritable traits meaning heterosis is not always needed to make improvement. When this happens the improvements in lowly heritable traits are overlooked and the effect of heterosis is lost (Daley, 2006).

Implications

Cattle utilize resources that are not usable by non-ruminant species. This results in the cattle herds being spread throughout the entire country, in multiple different climates and production systems. This diversity results in significant limitations on the ability to vertically integrate each segment. In contrast, the pork and poultry industries are vertically integrated. This has allowed pork and poultry producers to more easily and effectively capture the full benefit of heterosis and breed complementarity as they are responsible for the production of parent stock who will then produce terminal bound progeny. If beef producers were to use a similar system, where some producers are generating crossbred parent stock to sell as replacements to producers who would use them to make terminal-bound calves, the resulting increase in production could be substantial, similar to that of the pork and poultry industries. The key to this system lies in purchasing crossbred replacements and using terminal sires. If replacements are raised, then the opportunity to operate with more cows is lost due to resources devoted to developing heifers. Furthermore, if this system was more widely adopted the benefits could also be two-fold. The rancher who is producing the replacement females is marketing a potentially value-added product, in the form of a crossbred replacement. While the rancher who is buying the replacements is able to run more cows and produce the greatest amount of marketable weight possible.

Table 2-1. Number of heifers developed to meet replacement rate

Item	Value
Number of cows in herd	100
Replacement rate, %	14.7[a]
Number of heifers developed	25[b]
First service artificial insemination conception rate, %	58[c]
Number heifers required	15[d]
Overall pregnancy rate, %	88
Number of bred heifers available for sale	7[e]
Number of open heifers available for sale	3[f]

[a] (Tisor, 2017)

[b] Replacement rate % ÷ first time AI conception %

[c] (Diskin and Sreenan, 1980)

[d] Number of cows in herd * replacement rate %

[e] (number of heifers developed * pregnancy %) – number of heifers required

[f] Number of heifers developed * 0.15

Table 2-2. Assumed supplement formulation and nutrient concentrations for d 28 – breeding[a]

Item[b]	Concentration[c]
Formulation	
SBH, %	25
SBM, %	35
DDGS, %	40
Nutrient concentration	
CP, %	32.5
TDN, %	89.4
ME, Mcal/kg	3.26
NE_m, Mcal/kg	2.12
NE_g, Mcal/kg	1.43

[a] DM basis.

[b] SBH = soybean hulls; SBM = soybean meal; DDGS = distillers dried grains plus solubles; CP = crude protein; TDN = total digestible nutrients; ME = metabolizable energy; NE_m = net energy for maintenance; NE_g = net energy for gain.

[c] Based on tabular values from Preston (2017).

Table 2-3. Home raised system heifer assumptions and inventory calculations[a]

Item	Value
Cows in herd, n	100
Replacement rate, %[b]	14.7
Heifers required, n[c]	15
First service artificial insemination Conception rate, %	58
Heifers developed, n[d]	25
% of heifer crop retained[e]	57
% extra heifers retained[f]	42

[a] HR system = straight-bred Angus herd that produces its own replacement females

[b] (Tisor, 2017)

[c] Cows in herd * replacement rate %

[d] Replacement rate % ÷ first service artificial insemination conception rate %

[e] Heifers developed ÷ total heifer crop

n, total heifer crop = (herd weaning % ÷ 2)

[f] 100 – (replacement rate % ÷ heifers developed)

Table 2-4. Average daily gain of home raised replacement heifer calves during fence line weaning and the associated metabolizable energy intake

Item	Value
Days	28
Weaning weight, kg[a]	250
Average daily gain, kg	0[b]
Metabolizable energy intake, Mcal/d	10.8[c]
Total metabolizable energy required, Mcal	303[d]

[a] Weights are expressed as live weight

[b] An average daily gain of zero is assumed for this time period (Bailey et al., 2016)

[c] Metabolizable energy intake value is derived from NASEM (2016)

[d] Mcal/d * days

Table 2-5. Average daily gain of home raised replacement heifer calves from d 29 after weaning to breeding and the associated metabolizable energy intake

Item	Value
Days	223[a]
Beginning weight, kg[b]	250
End weight, kg[b]	364[c]
Average daily gain, kg/d[b]	0.51
Metabolizable energy intake, Mcal/d	15.09[d]
Total metabolizable energy required, Mcal	3,365[e]

[a] Number of days between d 29 post-weaning and d1 of breeding

[b] Weights are expressed as live weight

[c] Weight at 65% of mature weight

[d] Metabolizable energy intake value is derived from NASEM (2016)

[e] Metabolizable energy intake Mcal/d * days

Table 2-6. Metabolizable energy required for home raised system replacement heifer development from breeding to mid-gestation[a]

Item[b]	DMI, kg/d[c]	ME, Mcal/kg[c]	Mcal ME/mo[d]
Month 1	8.21	1.87	479
Month 2	8.50	1.87	495
Month 3	8.80	1.87	513
Month 4	9.09	1.87	530
Month 5	9.38	1.87	547
Month 6	9.73	1.92	580
Total ME required, Mcal			3,144

[a] Assumed gestation = 280 days, beginning weight = 65% of mature weight (364 kg), end weight = 80% of mature weight (448 kg)

[b] 31.1 d/month is assumed

days of gestation ÷ 9 months = 31.1 d/month

[c] Dry matter intake (DMI) and metabolizable energy (ME) are predicted values from NASEM (2016)

[d] Metabolizable energy (ME)/mo: dry matter intake (kg/d) * metabolizable energy (Mcal/kg) * 31.1 d/mo

Table 2-7. Monthly net energy and corresponding annual metabolizable energy requirement of mature cows in the home raised system[a]

Item[bc]	NEm Mcal/d[d]	NEm Mcal/mo[e]
Month 1	15.1	459
Month 2	16.0	486
Month 3	15.50	471
Month 4	14.50	441
Month 5	13.50	410
Month 6	12.70	386
Month 7	12.20	371
Month 8	12.00	365
Month 9	12.20	371
Month 10	12.70	386
Month 11	13.90	423
Month 12	15.60	474
Annual NE_m required, Mcal		5,043
Annual ME required, Mcal[f]		8,783

[a] HR system = straight-bred Angus herd that produces its own replacement females

[b] 30.4 days/month is assumed (365 days/yr ÷ 12 months = 30.4 d/mo)

[c] Timeline begins at calving

[d] Net energy for maintenance (NEm)/d value is predicted from NASEM (2016)

[e] NEm Mcal/mo: NEm (Mcal/d) * 30.4 d/mo.

[f] Metabolizable energy (ME)/yr calculation:

NEm to ME conversion

Diet total digestible nutrients (TDN) = 55% (example value necessary for calculation)

Digestible energy (DE) = TDN% *4.409

ME = DE * 0.82

NEm = 1.37 * ME – 0.138 * (ME^2) + 0.0105 * (ME^3) – 1.12

DE: 0.55 * 4.409 = 2.425 Mcal/kg

ME: 2.425 * 0.82 = 1.989 Mcal/kg

NEm: 1.37 * 1.989 – 0.138 * (1.989^2) + 0.0105 * (1.989^3) – 1.12 = 1.142 Mcal/kg

NE_m/yr ÷ 1.142 = 4415.94 kg/yr of diet

4415.94 * 1.989 = 8783.30 Mcal ME/yr

Table 2-8. Monthly net energy and corresponding annual metabolizable energy requirement of mature cows in the purchased replacement system[a]

Item[bc]	NEm Mcal/d[d]	NEm Mcal/mo[e]
Month 1	15.10	459
Month 2	16.00	486
Month 3	15.50	471
Month 4	14.50	441
Month 5	13.50	410
Month 6	12.70	386
Month 7	12.20	371
Month 8	12.10	368
Month 9	12.40	377
Month 10	13.10	398
Month 11	14.50	441
Month 12	16.50	502
Annual NE_m required, Mcal		5,110
Annual ME required, Mcal[f]		8,900

[a] PR system = purchased, bred, crossbred replacement females bred to a terminal sire

[b] 30.4 days/month is assumed (365 days/yr ÷ 12 months = 30.4 d/mo)

[c] Timeline begins at calving

[d] Net energy for maintenance (NEm)/d value is predicted from NASEM (2016)

[e] NEm Mcal/mo: NEm (Mcal/d) * 30.4 d/mo.

[f] Metabolizable energy (ME)/yr calculation:

NEm to ME conversion

Diet total digestible nutrients (TDN) = 55% (example value necessary for calculation)

Digestible energy (DE) = TDN% *4.409

ME = DE * 0.82

NEm = 1.37 * ME – 0.138 * (ME^2) + 0.0105 * (ME^3) – 1.12

DE: 0.55 *4.409 = 2.425 Mcal/kg

ME: 2.425 * 0.82 = 1.989 Mcal/kg

NEm: 1.37 * 1.989 – 0.138 * (1.989^2) + 0.0105 * (1.989^3) – 1.12 = 1.142 Mcal/kg

NE_m/yr ÷ 1.142 = 4474.61 kg/yr of diet

4474.61 * 1.989 = 8900 Mcal ME/yr

Table 2-9. Home raised system metabolizable energy requirement[a]

	Cows, n	ME/animal, Mcal[c]	Total ME, Mcal[d]
Cow herd	100[b]	8,783	878,300
	Heifers, n	ME/animal, Mcal	Total ME, Mcal[e]
Weaning – d 28	25	303	7,575
d 29 – breeding	25	3,365	84,125
Breeding – mid-gestation[f]			
Bred heifers	22	3,144	69,168
Open cull heifers	4	2,016	6,048
Total ME required, Mcal			1,045,216

[a] HR system = straight-bred Angus herd that produces its own replacement females

[b] Hypothetical value for the sake of the comparison

[c] Metabolizable energy (ME) to maintain a straight-bred cow for a year; value derived from Table 5

[d] Total ME required: cows, n * Mcal ME/animal

[e] Total ME required: heifers, n * Mcal ME/animal

[f] Values derived from Table 4; bred heifers are developed to mid-gestation, open cull heifers are developed and sold post pregnancy check

Table 2-10. Number of purchased replacement system females that can be run on the same resources as a 100-animal home raised system operation[a]

Straight-bred total metabolizable energy required, Mcal/yr	1,045,216[b]
F_1 cow metabolizable energy required, Mcal/yr	8,900[c]
Number of PR[c] system cows that can be maintained on the same resources as a straight-bred Angus herd	117[d]

[a] PR system = purchased, bred, crossbred replacement females bred to a terminal sire; HR system = straight-bred Angus herd that produces its own replacement females

[b] Value derived from Table 2-9

[c] Value derived from Table 2-8

[d] HR system total ME ÷ F_1 cow ME requirement/yr

Table 2-11. Comparison of home raised system versus purchased replacement system herd production parameters[a]

Item	HR system	PR system	% Change
Cows exposed, n	100	100	-
Cows calving, n	94.6[b]	95.5[c]	1.0
Cow wt, kg[d]	537.4	537.4	-
Weaning %	89.2[e]	91.4[f]	2.5
Kg weaned/cow exposed	220.4[g]	240.2[h]	8.8[k]
Calf weaning weight, kg	247.2[i]	262.8[j]	6.2[l]

[a] PR system = purchased, bred, crossbred replacement females bred to a terminal sire; HR system = straight-bred Angus herd that produces its own replacement females

[b] HR system number of cows calving is the 10-year average derived from the Livestock Enterprise Analysis (FINBIN, 2017)

[c] PR system number of cows calving is the number of cows in the HR system plus 0.9% increase (Cundiff et al., 1992)

[d] Cow weights for both the HR system and PR system are calculated from the 10-year average weaning weights (WW) from the Livestock Enterprise Analysis (FINBIN, 2017) and the NASEM (2016) estimate for WW as a % of cow body weight; cow weight = calf WW ÷ 0.46.

[e] HR system weaning % is the 10-year average derived from the Livestock Enterprise Analysis (FINBIN, 2017)

[f] PR system weaning % is the advantage brought by the calf (1.4 %) and the advantage of the crossbred cow (0.8%), which totals 2.2% (Cundiff and Gregory, 1999)

[g] HR system kg weaned/cow exposed is the 10-year average derived from the Livestock Enterprise Analysis (FINBIN, 2017)

[h] PR system kg weaned/cow exposed = F_1 calf weaning weight * weaning % ÷ number of cows exposed

[I] HR system calf WW is derived from the 10-year average derived from the Livestock Enterprise Analysis (FINBIN, 2017)

[j] PR system calf weaning weight is based on the WW advantage from the crossbred calf (7.4 kg) and the advantage of the crossbred cow (8.2 kg), which totals 15.6 kg

[k] % change for kg weaned/cow exposed calculation = (PR system kg weaned/cow exposed – HR system kg weaned/cow exposed) ÷ HR system kg weaned/cow exposed

[l] % change for calf WW calculation = (PR system WW – HR system WW) ÷ HR system WW

Table 2-12. Comparison of weight of cattle produced by production system[ab]

HR system		
Calves sold at weaning	Steers	Heifers
Number of animals[c]	45	20
Average weaning weight, kg	254.0	240.4
Total weight, kg	11,430.0	4,808.0
Combined steer and heifer weight at weaning, kg	16,238.0	
Marketable bred heifers[d]		
Number of bred heifers	-	7
Average weight, kg	-	408.7
Total weight at mid-gestation, kg		2,860.9
Open cull heifers		
Number of open cull heifers	-	3
Average weight, kg	-	388.7
Total weight after pregnancy diagnosis, kg		1,166.1
Total weight, kg	20,265.0	
PR system	Calves	

Number of animals[e]	107
Average weaning weight, kg	262.6
Total weight, kg	28,098.2
Difference between systems, kg	***7,833.2***

[a] PR system = purchased, bred, crossbred replacement females bred to a terminal sire; HR system = straight-bred Angus herd that produces its own replacement females

[b] All weights are shrunk

[c] Based on a herd weaning % of 89.2 (FINBIN, 2017), which results in 44.6 steers and 44.6 heifers. Only 20 heifers are sold at weaning since 25 are kept for development.

[d] Bred females sold at mid-gestation, that did not conceive to first time AI

[e] Based on a herd weaning % of 91.4% (Cundiff and Gregory, 1999)

Table 2-13. System gross revenue comparison[a]

	HR system		PR system	
Calf sales	Steers	Heifers	Steers	Heifers
Number of animals[b]	45	20	53.5	53.5
Average weaning weight, kg	254.0	240.4	269.9	255.4
Total weight, kg	11,430.0	4,808.0	14,440.0	13,664.0
Price received, $/kg[b]	4.03	3.57	4.03	3.57
Total revenue, $	63,227		106,974	
Heifer sales	Bred	Cull	Bred	Cull
Number of animals	7	3	-	-
Total weight, kg	-	1,166.2	-	-
Price received,$/hd.[c]	1,378.0	-	-	-
Price received, $/kg.[b]	-	3.15	-	-
Gross sales income, $	9,646.0	3,674.0	-	-
Total revenue, $	13,320.0		-	-
Cull cow sales				
Number of animals	15		15	
Total weight, kg	8062.7		8062.7	
Price received, $/kg	1.30		1.30	
Gross sales income, $	10,482.0		10,482.0	

Total system revenue, $	87,029.0	117,456.0

[a] PR system = purchased, bred, crossbred replacement females bred to a terminal sire; HR system = straight-bred Angus herd that produces its own replacement females

[b] All weights are shrunk

[c] Average South Dakota feeder calf price in Sept. – Nov. 2017 (LMIC, 2018)

[d] Average South Dakota feeder heifer price in October 2017 (LMIC, 2018)

[e] Derived from the Livestock Enterprise Analysis average price received for bred heifers (FINBIN, 2017)

Table 2-14. System expense comparison

Item	HR system	PR system
Number of heifers developed or purchased	25	15
Development cost or purchase price, $/animal[b]	488.0	1378.0
Heifer expense, $	12,200.0	20,670.0
Number of cows	100	117
Cow expense, $/hd[a]	620.0	624.0
Cow herd expense, $	62,000.0	73,008.0
Total expense, $	74,200.0	93,678.0

[a] PR system = purchased, bred, crossbred replacement females bred to a terminal sire; HR system = straight-bred Angus herd that produces its own replacement females

[b] Derived from the livestock enterprise analysis (FINBIN, 2017)

Table 2-15. System net income comparison (summary of Tables 13 and 14)[a]

Item	HR system	PR system
Income		
Weaned calves, $	63,227.0	106,974.0
Bred/cull heifers, $	13,320.0	-
Cull cows, $	10,482.0	10,482.0
Expenses		
Developing heifers, $	12,200.0	-
Purchased heifers, $	-	20,670.0
Cow herd, $	62,000.0	73,008.0
Net income, $	12,829.0	23,778.0
Difference, $		+10,949.0

[a] PR system = purchased, bred, crossbred replacement females bred to a terminal sire; HR system = straight-bred Angus herd that produces its own replacement females

CHAPTER THREE

COMPARING THE EFFICIENCY OF DEVELOPING ANGUS VERSUS SIMANGUS HEIFERS USING THE INSENTEC SYSTEM

Introduction

Assessing post weaning growth and feed efficiency of different biological types of cattle is important when attempting to effectively utilize different breeds of cattle to meet production goals (Gregory et al., 1979). Cross-breeding and complementarity are tools to create cattle that out perform their parents and if correctly applied be better suited for their production environment (Ritchie et al., 1999). The greatest impact of heterosis is seen in lowly heritable traits but there are still more easily measured advantages, like additional weight at weaning and a year of age (Weaber and Spangler, 2013). For example, data from Laster et al. (1979), shows Continental cross cattle have greater post weaning growth than straight-bred British cattle. The full benefits of heterosis are usually fully realized in traits like lifetime production (Cundiff and Gregory, 1999).

The objective of this research was to compare the growth, feed intake, and feed efficiency of purebred Angus and crossbred SimAngus heifers. Our hypothesis was that crossbred SimAngus heifers would have an advantage in growth and feed efficiency as a result of heterosis.

Materials and Methods

This experiment was conducted at the SDSU Cow-Calf Education and Research Facility (CCERF) from December 9th, 2016, to May 24th, 2017. All procedures involving live animals were approved by the South Dakota State University Institutional Animal Care and Use Committee (approval number 16-064A).

Facility

Heifers were housed in two partially-covered confinement pens (54.9 m^2 per animal total; 3.5 m^2 per animal covered) that were equipped with 12 Insentec Roughage Intake Control feed bins and 2 Insentec watering units (Insentec system; Insentec Roughage Intake Control System, Hokofarm Group, Markenesse, The Netherlands). Upon arrival, a half-duplex electronic identification (e**ID**) tag (Allflex, Europe, UK) was placed in the right ear of each animal. The eID tag numbers for each animal were programmed into the Insentec system to allow each individual animal access to the feed and water bins while simultaneously recording feed and water disappearance. The Insentec system functions via an electronic antenna that detects the eID when an animal approaches the feeder. Once the animal places their head into the feeder, a light beam is disrupted and the head gate lowers allowing access to the bin. The system records eID number, bin ID, initial and ending weight of the bin and entry and exit times for each intake event.

Animals

On November 4th, 2016, 28 purebred Angus and 32 SimAngus bred heifers (initial BW = 284 kg, ± 5.6 kg) were moved into the partially covered confinement pen described previously. The heifers used in this trial were part of a larger, two-year trial designed to examine the effects of two dietary treatments on heifer growth, feed intake, feed efficiency, water intake, and various reproductive parameters. As such, the heifers were stratified by breed, initial weight, sire and educational usage then randomly assigned to one of two dietary treatments in 1 of the 2 pens such that breed and educational usage were equally represented within each dietary treatment and within each pen. Educational usage includes animal shown in The SDSU Little International, and any class demonstrations. Dietary treatments were randomly assigned to 10 of the 12 Insentec feeders in each pen. Two of the feeders in each pen were not used. The heifers were then randomly assigned to their designated feeder (n = 3 per feeder) prior to the training process being initiated.

The breed composition of the SimAngus heifers consisted of 3/8 (n=2), 1/2 (n=6), 5/8 (n=14), and 3/4 (n=7) Simmental while the rest of the pedigree was Angus.

Sires of heifers included purebred Angus (n = 6), SimAngus (n = 4), and purebred Simmental (n = 3). Expected progeny differences were used for genetic selection of the sires, with emphasis on different combinations of calving ease, birth weight, growth, maternal ability, carcass merit, and various economic indices. Genetically, each sire excels in different traits, and all sires rank in the top 5% of their respective breed for at least 1 trait and some the top 1% for various traits. Typically to ensure cattle with phenotypic quality are produced, sires chosen need to have already proven to produce progeny with excellent skeletal quality, muscle, body, fleshing ability, growth, udder quality and disposition.

Feeding Management

Heifers were trained to use the Insentec system over a 3-week period. During the first week, the head gates on the system were left open to allow any animal to consume feed out of any feeder. In the second week, the head gates were closed, but each animal still had access to every feeder. Finally, during the third week, access was restricted to the feeder assigned to each individual heifer. Feeding occurred at 0800 h and 1500 h. Feed bunks were observed at approximately 0700 h each day, a slick bunk management system was used but daily feed allotments were adjusted to allow for approximately *ad libitum* intake. Feed refusals were collected and sampled if greater than 1 kg remained in the bunk from the previous day.

Diets were mixed in a Kuhn Knight 3125 mixer (Kuhn North America, Brodhead, WI) and timed to allow 3 minutes of mixing time. Heifers were fed common basal diets from d 1 – 98 and from d 99 – 167. However, the energy concentration of the diet was reduced from d 99 – 167 because of underestimated heifer performance during the first period (Table 1).

Data Collection

Six heifers were removed from the study, one of which was a freemartin, while the remaining five heifers failed to adapt to the Insentec system. Those heifers remained in the feeding pen for the duration of the 167-d study; however, their weight, feed intake, and feed efficiency data were removed prior to analysis. Data from the remaining 54 heifers (n = 25 Angus and n = 29 SimAngus) were used for statistical analysis. At the beginning of the trial, 2 consecutive weights were collected using a chute (Silencer, Moly Manufacturing, Lorraine, KS) and certified (5/11/2016; NBS Calibrations, Bloomington, MN) scale (Tru-Test, Mineral Wells, TX; ± 0.22 kg) and averaged to determine initial

BW. Individual BW were collected before feeding on d -1, 0, 98, and 167. Initial BW was the average of d -1 and 0, and final BW was collected on d 167. Feed intake data was generated by the Insentec system and included the beginning time and weight and ending time and weight for each feeding bout (entry and exit of feed bin) for each animal. From that data, average daily intakes were calculated and corrected for dry matter.

Sampling and Laboratory Analysis

Individual feed ingredient samples were collected weekly to determine dry matter (DM) content, then composited into monthly periods prior to nutrient analysis. Feed samples were analyzed in duplicate for DM, ash, nitrogen (N), neutral detergent fiber (NDF), acid detergent fiber (ADF), and in triplicate for acid detergent lignin (ADL), and ether extract. Dry matter was measured by drying at 55°C for 24 h, and ash was determined by combustion (500°C for 8h). Nitrogen content was analyzed by the Dumas procedure (method no. 968.06; AOAC, 2016; rapid Max N exceed; Elementar, Mt. Laurel, NJ). Neutral detergent fiber was measured as described by Van Soest et al. (1991) and included additions of α-amylase and sodium sulfite; ADF was measured nonsequential to NDF (Van Soest et al., 1991). Acid-detergent lignin was measured after thoroughly soaking ADF residue in 72% (wt/wt) sulfuric acid for 3 h and agitating ADF residue in acid each 30 min (Van Soest and Robertson, 1980). Ether extract was measured using the ANKOM^{XT10} Extractor, (ANKOM Technology, Macedon, NY), and followed the procedure as described by (ANKOM, 2018). Measures of NDF, ADF, and ADL were corrected for ash content which was measured by combustion (500°C for 8 h).

Estimation of Dietary Energy and Animal Requirements

Diet total digestible nutrients (TDN) was calculated by the equation:

$$TDN = 0.98 \times (100 - NDF_N - CP - ash - FA - 1) + 0.93 \times CP + 2.25 \times FA + 0.75 \times (NDF_N - lignin) \times [1 - (lignin/NDF_N)^{.667}] - 7$$

where NDF_N = N-free NDF, FA = fatty acids, CP = crude protein (Weiss, 1993).

Total digestible nutrients were then converted to digestible energy (DE) using the equation:

$$DE = TDN \times 4.409$$

Then to metabolizable energy (ME) using the equation:

$$ME = DE \times 0.82$$ (NASEM, 2016).

Metabolizable energy was then used to determine dietary net energy for maintenance (NE_m) and net energy for gain (NE_g) using the following equations from NASEM (2016).

$$NE_m = 1.37 \times [ME] - 0.138 \times [ME]^2 + 0.0105 \times [ME]^3 - 1.12$$

$$NE_g = 1.42 \times [ME] - 0.174 \times [ME]^2 + 0.0122 \times [ME]^3 - 1.65$$

The following equations used to calculate animal requirements and performance were derived from the NASEM (2016).

NE_m required = $0.077 \times SBW^{0.75}$, where SBW = shrunk body weight

Feed for maintenance (FFM) = NE_m required / dietary NE_m

Empty body weight (EBW) = 0.891 x SBW

Empty body gain (EBG) = SWG x 0.956, SWG = shrunk weight gain

Equivalent shrunk body weight (EQSBW) = SBW x (SRW /FSBW), where SRW = shrunk reference weight and FSBW = final shrunk body weight

Equivalent empty body weight (EQEBW) = 0.891 x EQSBW

Retained energy (RE) = 0.0635 x $EBW^{0.75}$ x $EBG^{1.097}$

Feed for gain (FFG) = RE/ dietary NE_g, where RE = retained energy

Predicted feed intake = FFM + FFG

Residual feed intake from NRC (RFI_{NRC}) = actual feed intake – predicted feed intake from NRC (NASEM, 2016)

Statistical Analysis

Animal performance was analyzed as a randomized complete block design using the MIXED procedures of SAS (SAS Inst. Inc., Cary, NC) with fixed effects being block and dietary treatment with animal as the random effect. Breed effects were considered significant if $P \leq 0.05$, and tendencies were reported at $0.06 \leq P \leq 0.10$.

Results and Discussion

Treatment means for heifer performance are presented in Table 2. At the start of the trial there was no difference in initial BW between breeds. Angus heifers had a greater ADG than SimAngus heifers in both the first period (d 1 – 98; $P \leq 0.02$) and second period (d 99 – 167; $P \leq 0.02$). Consequently, cumulative ADG was greater ($P \leq 0.01$) in the Angus than in SimAngus heifers. This result was somewhat unexpected as most data would suggest that calves sired by Continental breeds (e.g., Charolais, Simmental, etc.) would gain faster than Angus-sired calves. Laster et al. (1976), reported that at 400 and 550 days of age, Simmental-cross heifers were heavier than straight-bred Angus heifers. They later observed a postweaning growth advantage by Continental-cross heifers over Hereford-Angus crossbred heifers and indicated that larger, later maturing breeds exhibit greater growth potential as age increases (Laster et al., 1979). Smith et al. (1976) demonstrated that crossbred Simmental and Charolais-sired steers were heavier after 180 d post-weaning than Angus-sired steers. Furthermore, Gregory et al. (1994) observed that Simmental and Charolais-sired cattle exhibited the greatest ADG when compared to Angus and Hereford sired cattle. In contrast, Mandell et al. (1998) found no difference in ADG between Simmental and Hereford cattle. It is possible that the difference in growth between Angus and SimAngus heifers in our trial is simply due to the small sample size, the small number of sires represented, and the selection emphases used to produce the heifers.

Another explanation, greater DMI by the Angus cattle is what facilitated the observed growth advantage over SimAngus. Dry matter intake was greater in period two (d 99-167; $P \leq 0.01$)) and overall ($P \leq 0.03$) for Angus heifers than SimAngus heifers. It is difficult to speculate why the Angus cattle consumed more DM. The assumption was that DMI would not have been different, and if a difference was detected it would have favored the SimAngus heifers. This assumption is supported by Mandell et al. (1998), who found that Simmental cattle had a greater DMI than Hereford cattle; but when fed to a similar backfat finish, Hereford steers reached an earlier endpoint than Simmental. This was attributed to an increased maintenance requirement in Simmental cattle, consistent with the findings of Ferrell and Jenkins (1985). In contrast, Myers et al. (1999) observed no difference in dry matter intake between Simmental and Angus crossbred cattle when compared at a common backfat thickness.

Observed ME intakes were not different in the first period; however, during period two ($P \leq 0.01$) and overall ($P \leq 0.03$) ME intakes were greater in Angus heifers than in SimAngus heifers. This concurs with previously discussed data, in that since the Angus heifers consumed more DM in period two and cumulatively, ME intake was also greater. Data reported by Smith et al. (1976) demonstrated that crossbred Simmental and Charolais sired steers required less ME per unit of gain. Similarly, Gregory et al. (1994) reported that, in a gain constant period from 310 to 540 kg, Simmental cattle required less ME, and Angus and Hereford cattle were less efficient (gain/Mcal of ME) than Simmental, Limousin, Braunvieh and Charolais cattle. In contrast, a study conducted by Ferrell and Jenkins (1985), compared breed effects of Simmental and Hereford cattle on ME requirements for maintenance and gain. Their findings showed Simmental cattle had greater ME intakes than Hereford cattle and the same was true for empty body weight gain; however, Herefords gained more efficiently than the Simmental cattle.

Residual feed intake (RFI) has gained increasing attention in the beef industry in recent years. In most instances, RFI is calculated relative to a contemporary group of animals. However, we calculated RFI as the difference between predicted (NASEM, 2016) and actual feed intake, then compare that difference between animals. Our calculation will be noted as RFI_{NRC} to delineate it from the more common RFI calculations. No differences were observed in the RFI_{NRC} between Angus and SimAngus heifers. However, predicted DMI was greater for Angus in period two (d 99-167; $P \leq 0.04$) and tended to be higher cumulatively ($P \leq 0.06$). It is difficult to make comparisons relative to other literature on RFI due to the different methodology used to calculate predicted DMI. Equations published by NASEM (2016) allowed for the calculation of predicted DMI by using the actual net energy of the feed and each individual animal's growth to determine how much DMI it would take to achieve that level of growth. In contrast, Herd and Bishop (2000) calculated predicted feed intake from a multiple regression of feed intake (FI) on metabolic mid-test weight and ADG. Similarly, Archer et al. (1997) predicted FI by calculating a partial regression coefficient of FI on ADG and FI on metabolic mid-weight, then comparing the predicted FI to actual FI to determine an RFI value. This is different to how RFI was predicted in our study since our predicted values was not based on values relative to a contemporary group, rather the predictive equations that allowed for the calculation of DMI given animal growth and the NE_m and NE_g of the diet. Through using this method of calculating RFI, the contemporary group is essentially all of the cattle used to build the predictive equations. We feel this is a far more robust method of comparing the feed efficiency of beef cattle.

Our results indicate that Angus heifers were more efficient at converting feed to gain (ADG ÷ average DMI) over the duration of the trial ($P \leq 0.05$); however, there were no differences between the breeds in either period. Though not statistically different, in both periods Angus had a numerically higher G:F. Perhaps, the cumulative test granted the sensitivity to pick up the difference in G:F over both periods combined. Which was demonstrated by numerically greater variance of periods (period 1 SEM = 0.003; period 2 SEM = 0.004) compared to the cumulative measure (SEM = 0.002). Similarly, Laborde et al. (2001) found that Simmental cattle were less efficient than Red Angus, though it was noted selection emphasis was weighted toward birth weight and calving ease in the Simmental cattle, whereas growth was emphasized in the Red Angus cattle. Rust et al. (1995) also demonstrated that selected Hereford steer groups were more feed efficient than crossbred groups of cattle. Conversely, Myers et al. (1999) saw no difference in feed efficiency between Simmental and Angus crossbred cattle when compared at a common backfat thickness.

Collectively, data indicate that in this herd the straight-bred Angus cattle have greater genetic propensity for growth, feed intake and feed efficiency. It is possible that the recorded advantage in performance and efficiency could be due a simple increase in DMI. Since the Angus heifers consumed more feed, they had more energy available for gain. It is also plausible that the maintenance requirement of the breeds could be the source of the SimAngus heifers feed efficiency disadvantage. Laurenz et al. (1991) reported that Simmental cows had a 16.1% greater daily ME requirement than Angus cows. Differences in maintenance and efficiency of gain can be associated with metabolic activity of visceral organs such as the gut or liver (Ferrell, 1988). Breed types can also affect the efficiency of utilization of ME for gain as breeds with a greater propensity for growth and mature size also have a greater maintenance requirement (Ferrell and Jenkins, 1985). Increased milk production potential has also been linked to increased maintenance requirements (Ferrell and Jenkins, 1988). However, as maturity progresses there exists a potential advantage in finishing cattle that could help offset the difference in efficiency.

As Simmental cross cattle can have an advantage in carcass weight and lean yield (Laborde et al., 2001).

It should also be noted that this experiment lacks the numbers to offer a strong representation of Angus and SimAngus crossbred cattle. In this herd, selection emphasis is placed on cattle that feature low birth weights and high calving ease while still exhibiting exceptional growth potential. Selection emphases used in the herd that produced these heifers supports a conclusion that the advantage seen in the Angus cattle over the SimAngus heifers could be due to greater genetic pressure for low birth weight and calving ease in the SimAngus heifers than the Angus heifers.

Implications

Crossbreeding has well documented effects on productivity and longevity of beef cows. In the current experiment, Angus heifers performed better and were more efficient at converting feed to gain. However, given the small sample size and the limited genetic diversity represented in this trial, further research would be advisable prior to developing any strong conclusions.

Table 3-1. Ingredient and calculated nutrient composition of the diets

Item	d 1-98	d 99-167
Ingredient, % of diet dry matter		
Hay	24.7	53.6
Silage	58.9	35.9
Supplement[a]	16.4	10.5
Nutrient composition, dry matter basis		
Diet DM, %	56.9	60.6
NE_g, Mcal/kg	1.06	0.92
NE_m, Mcal/kg	1.68	1.51
ME, Mcal/kg	2.58	2.39
CP, %	8.7	8.0

[a] Contained: soyhulls, dried distillers grains plus solubles, monensin, vitamins and minerals.

Table 3-2. Effect of breed on heifer growth, intake, and feed efficiency

	Breed			
Item[ab]	Angus	SimAngus	SEM[c]	*P*-value
Initial weight, kg	268	276	5.6	0.28
d 1 – 98				
d 98 weight, kg	386	385	7.3	0.93
ADG, kg/d	1.21	1.12	0.029	0.02
DMI, kg/d	9.29	8.96	0.209	0.26
G:F	0.13	0.12	0.003	0.12
ME intake, Mcal/d	23.9	23.0	0.54	0.26
Predicted DMI, kg/d	7.79	7.48	0.189	0.24
RFI_{NRC}	1.50	1.48	0.151	0.93
d 99 – 167				
d 167 weight, kg	430	420	8.1	0.37
ADG, kg/d	0.64	0.51	0.041	0.02
DMI, kg/d	9.05	8.18	0.182	< 0.01
G:F	0.07	0.06	0.004	0.11
ME intake, Mcal/d	21.6	19.5	0.44	< 0.01
Predicted DMI, kg/d	7.55	6.79	0.257	0.04
RFI_{NRC}	1.50	1.38	0.185	0.62

d 1 – 167				
ADG, kg/d	0.97	0.86	0.026	< 0.01
DMI, kg/d	9.19	8.64	0.183	0.03
G:F	0.11	0.10	0.002	0.05
ME intake, Mcal/d	23.0	21.6	0.46	0.03
Predicted DMI, kg/d	7.58	7.09	0.191	0.06
RFI_{NRC}	1.61	1.55	0.131	0.73

[a] ADG = average daily gain, DMI = dry matter intake, G:F = gain to feed ratio, ME intake = metabolizable energy intake, RFI_{NRC} = residual feed intake calculated using predicted feed intake from NASEM (2016)

[b] All weights are shrunk

[c] Standard error of the mean

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